The Evaluation Methodology of Ecological Construction of Gully Villages on Loess Plateau: The Case Study of Chang Wu County, Shaanxi Province, China

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Abstract

Gully regions of Loess Plateau, one of the earliest human settlement areas and one of the most fragile ecological areas in China, are facing challenges for future development. As the smallest social units on Loess Plateau, gully villages own large amount of agricultural population. However, due to unreasonable development planning and the loss of developing directions, gully villages are gradually disappearing. Based on the practical investigation of Gansu and Shaanxi province in China, this paper is focused on the main influential factors for the development of gully villages, and establishes a quantitative evaluating method for ecological construction. Furthermore, this paper takes typical villages in Chang Wu County, Shaanxi province, China, as study objects, selects and classifies evaluation factors, and completes the quantitative evaluation on the suitability and sensitivity of ecological construction based on relative evaluation standards, which will provide developing directions and suggestions in the future ecological development.

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1. Research background

1.1 An overview of villages in gully regions of Loess Plateau

The Loess Plateau is located in the west of China, which is covered with 30m-300m calcareous yellow soil, about 530 thousand square kilometers, accounting for 1/l8 of total Chinese territory (Tianzeng-Zhang, 1993).

The administrative areas of gully regions of Loess Plateau include 6 cities, 18 counties in total, a population of about 4.3 million, and a total area of about 14.8 thousand square kilometers (Figure 1). It is also one of the earliest human settlement areas and one of the most fragile ecological areas in China (Xiangming & Ruo-qi, 2008). In this region, gullies and terrains are complex, tableland, slope, ditch form the basic terrain features (Reconnaissance Survey Planning, Design and Research Institute of Yellow River Conservancy Commission, 1987). Generally, on the Loess Plateau, economy is underdeveloped; living conditions are not good; and the construction of infrastructure is not enough. In addition, living and ecological environment is vulnerable, all of which cause lower population density here than other areas in the southeast of China.

The distribution of village location in this region is dispersed and has unique local characteristics, mainly distributed in table-land, ditch, slope and gully. The village forms can be divided into centralized villages and dispersed villages (Xi-qi Lu, 2013). Centralized villages are distributed in a relatively ac-cumulating way, which are mainly tableland villages. The dispersed villages are mainly gully villages, slope villages and ridge villages (Figure 2), most of which are planned by regular roads or net road; and there are also some dispersed villages planned by irregular roads system.

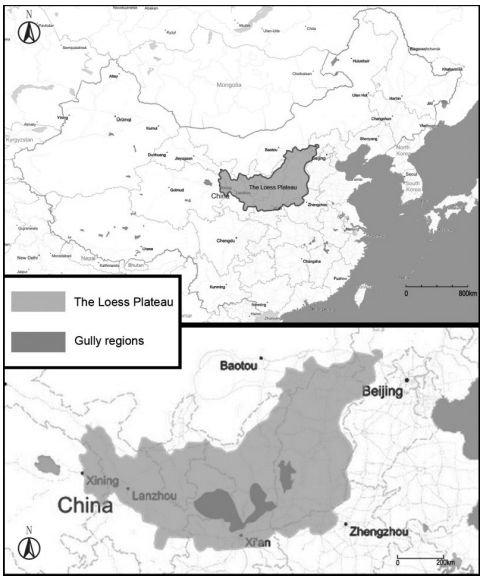


Figure 1. Loess Plateau and gully regions.

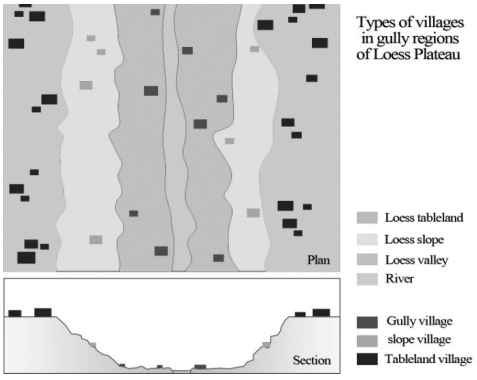


Figure 2. Types of gully villages in gully regions of Loess Plateau.

1.2 Overviews of Chang Wu County

Chang Wu County is located in east longitude 107°38′49″-107°58′02″ , northern latitude 34°59′09″-35°18′37″ in gully regions on Chang Wu tableland in Xian Yang city, Shaanxi province of China (Figure 3). There are 6 towns, 5 towns, 160 villages; the total area is 567 square kilometers. The population is about 1,804,000; among them 162,668 is agricultural population (Shaanxi Province Bureau of Statistics, 1999). Until 2007, cement concrete roads have already covered every village. Within this area, gully divides tableland into tableland, slope, and gully. On tableland, lands are flat and wide, fertile, and with convenient transportation system, thus this area is usually the main economic area and densely populated area.

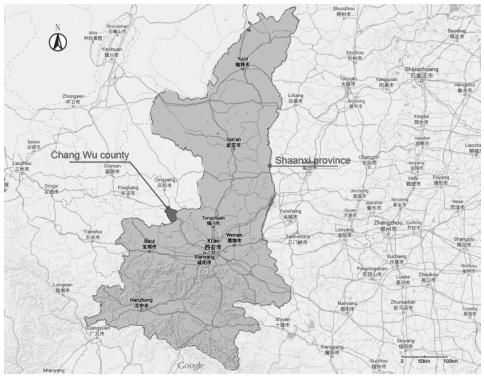


Figure 3. The location of Chang Wu County in Shaanxi province.

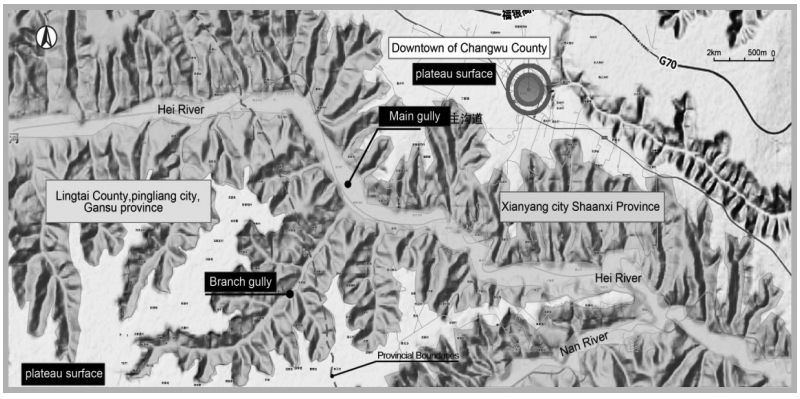


Figure 4. The topographic distribution of Changwu County.

Large scale cities and towns are usually distributed in the tableland area, while villages are distributed along the tableland line and gullies (Figure 4).

In recent years, with the adjustment of industrial structure and rural economic development, human settlements enter a drastic transform period. Slope villages and gully villages are moving to the tableland, where cities and towns are expanding blindly, thus the contradiction between land and human are intense, water and soil loss is more serious, and people's life are often threatened by landslide or collapse.

2. Distribution char acteristics of gully villages

2.1 The spatial division of human settlements in gully regions of Loess Plateau

The width of gully, arable land, land flatness, transportation conditions and water sources are the important factors that influence human settlement environment. In this paper, starting from human settlement environment, according to the natural geography and the influence of rivers on people's living environment, the tributary of gully region can be divided into three levels, each of them corresponding to a different gully (Figure 5).

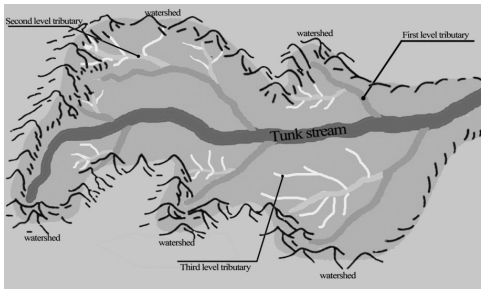


Figure 5. Spatial division diagram of human settlements in gully regions.

2.1.1 First level tributary

Yellow River is one of the most important rivers in China. Those braches of rivers, entering it directly, are called the first level tributary, which come to be the widest gully. These gullies usually have the best-cultivated lands and supply the best living environment. Cities are mainly located in these gullies and also some towns and villages, thus these first level tributaries are the most developed regions and own best living condition in the entire gully region. Large-scale towns and cities are usually located in these first level tributary regions.

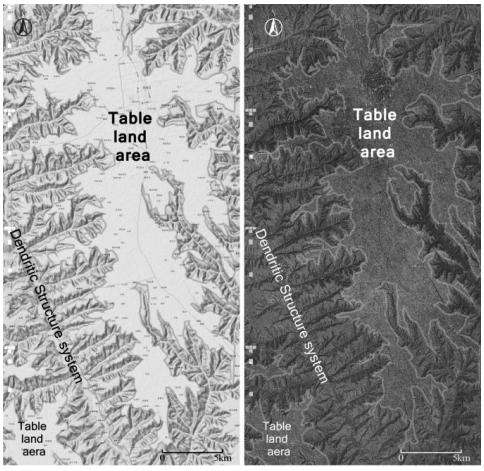
2.1.2 Second level tributary

Second level tributary means those tributaries that enter the first level tributary directly and length is over 50km. Because of certain landscape there, settlement typologies are mainly towns, and there are lots of provincial roads passing by, even national roads. Although the developing conditions of this region are not as good as the first level tributary region, there are still towns and township government for the good transportation conditions. Towns and big villages are usually located in these second tributary regions.

2.1.3 Third level tributary

The third level tributary means its length is among 50km, there are usually 5km small scale rivers. The conception here is in compliance with what used in the protection and conservation of soil and water (Hanxue, Ruoqi & Linan, 2005). The gullies' width is usually about 100m to 1000m; the narrowest part is just several decameters. Due to the limitation of natural landscape, almost no town is located in just some villages, the smallest living units are located there. Gully villages are the common living unit in these third level tributary regions.

Due to the different developing conditions, cities and large scale towns are mainly located in the first level tributary regions; towns and big villages are located in the second level tributary regions for the convenient transportation; gully villages are the mainly human settlements in the third level tributary regions for its poor developing conditions. In order to achieve better development in the third level tributary regions and improve the living conditions of the gully villages, gully villages of the third level tributary regions are the main analysis objects.



NASA topographic map NASA satellite map

Figure 6. Branch system of gullies on Dong Zhi plateau in Long dong area.

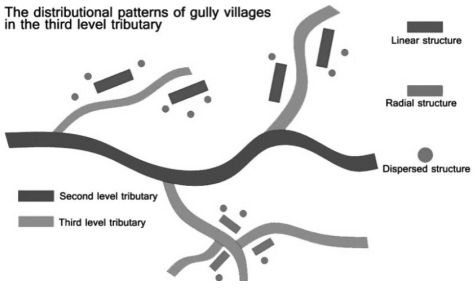


Figure 7. The distributional patterns of gully villages in the third level tributary.

2.2 The distributional patterns of gully villages

In different gullies of Loess Plateau, the relationship between human living environment and natural ecology is similar. Even in different tributaries, they all share some similarities (Qinghua, 2004). The junction areas of third level tributary actually is the same as senior level tributary; they all have ecological sensitive areas and also the developing area for human settlements. In the junction of first level tributary, cities and towns always develop there; while in the junction of third level tributaries, large-scale villages and commercial public infrastructure are located there. From the overall level, gully villages are distributed in dendrite system (Figure 6) and form a whole dendrite structure.

From partial level, gully villages can be divided into three distributional patterns (Figure 7). Similar to senior level gullies, the distribution of most gully villages in the third level gullies is also in the form of linear structure, they are along the gullies and similar to the distribution of cities and towns. In the junction of the third level gullies, villages are along the directions of gullies, come to be radial structure. There are also some villages distributed in a dispersed structure for the limited cultivated lands and living lands. At present, due to the abandon of cave dwellings in the center of villages, those dispersed residents start to live near each other, which actually is good for the villages' integration.

2.3 Classification of gully villages' distribution

Gully villages are located in the gully region of third level tributary, with ridges and plateau surface as boundary line. The third level tributary gully is usually made up by main gullies with rivers and branch gullies without rivers, which are also the smallest settlement typologies in the Loess Plateau. The main transportation is by river and road. According to the different locations of these gully villages, they can be divided into two kinds: villages located in the main gullies and villages in the branch gullies (Figure 8).

Figure 8. Two kinds of gully villages, which are located in the third level tributary gully.

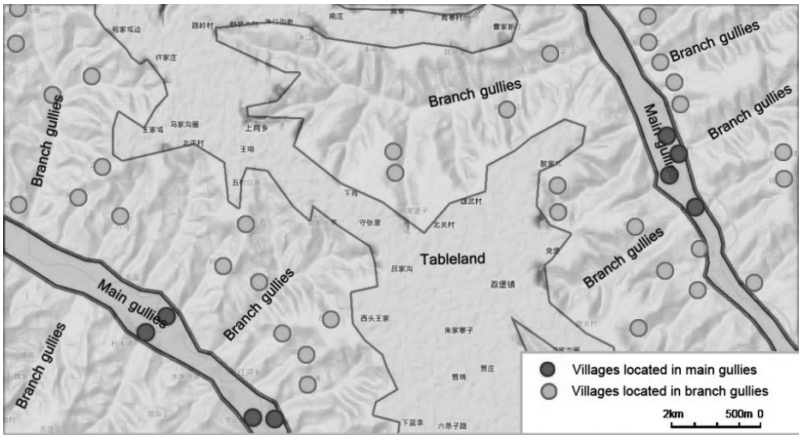


Figure 9. Location of Zhang Jia He village.

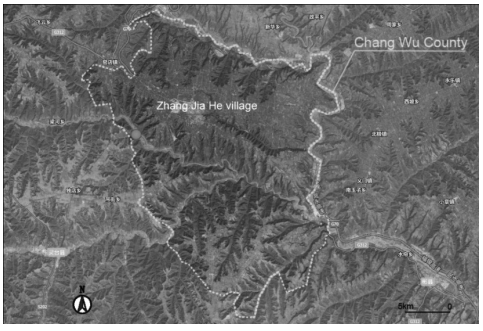


Figure 10. Panorama of Zhang Jia He village.

2.3.1 Villages located in main gullies

Located in the main gullies of the third level tributary, gully villages own broad land and near water sources and main roads. Thus, the village size is larger than those located in gully branches, and the population density is much higher. The following figure shows a typical main gully village, the name of that is Zhang Jia He village. There are 135 families, 516 people, 102.33 hectares cultivated land, and the annual per-capita income is about 5000 RMB (816 USD). (Figure 9, Figure 10 and Figure 11).

In addition, even in the same third level tributary gully, the distributions of gully villages are still different from each other. If the villages of branch gullies are closed to the gullies junction or plateau surface, the developing condition of these villages will be influenced greatly (Lei wang, 2005). Cities and towns with larger population and resources are usually distributed in the junction of gullies. For those villages that are located in the junction of gullies, near plateau surface, they own better developing conditions than other villages. Generally, the most of largest scale villages are located in the junction of branch gullies for the broad land.

Figure 11. Zhang Jia He village is located in the main gully of the third level tributary.

2.3.2 Villages located in branch gullies

Limited by geography, villages located in branch gullies of the third level tributary, are in the form of a closed space, which makes them an independent, quiet and harmonious neighborhood living unit in Loess Plateau. The scale of these villages is small, and the population there is small. The following figure shows a typical branch gully village, the name of that is Wu Jia Shan village. There are 68 families, 258 people, 30.93 hectares cultivated land, no primary school and clinic; infrastructure is poor; and the annual per-capita income is less 2000RMB (327 USD) (Figure 12, Figure 13, Figure 14).

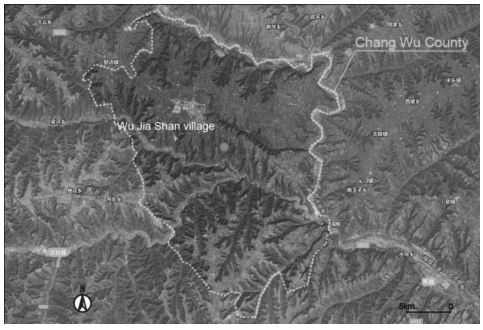


Figure 12. Location of Zhang Jia He village.

Figure 13. Wu Jia Shan village is located in the branch gully of the third level tributary area.

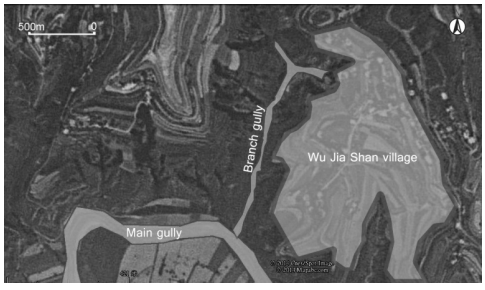


Figure 14. Present distribution of Wu Jia Shan village.

3. Quantitative evaluation on the ecological construction conditions of gully villages

Based on the established ecological system of tableland, the ecological construction of gully villages aims to achieve environmental sustainable development through practical investigation, documentation research, and by contemporary ecological theory and methods, mainly according to the following steps (Figure 15).

Although the distribution of gully villages in main gullies and branch gullies are different, their component elements, distribution forms and the developing influenced elements are almost the same. There is no basic difference between these two kinds of villages, only for the developing conditions, they are different, thus this paper will use a same method to evaluate these two kinds of villages.

Evaluation index is defined according to relative standards, regulations and domestic value, and take the present developing situation and trend into consideration. Index standard owns foresight, but not the final aim. Along with the social development, there will be more contents, thus these index will be changed. These standards are in a certain historical category and they will own different values under different social and economic conditions.

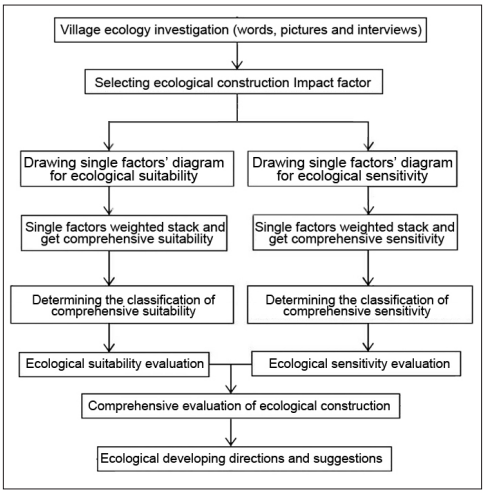


Figure 15. Analysis process of quantitative evaluation of ecological construction.

Due to the different contributions of these index factors to the ecological aim, these factors should be treated differently during the process of comprehensive evaluation, thus deciding the importance of different index is the basic of evaluation, which is not only related to the understanding of the importance of social, economic and natural, but also related to the implementation of policy and regulations. Index weights of multi-objective decision reflect the different important degrees of each index. The ecological index evaluation of gully villages' human living ecology is a typical multi-objective decision; each index reflects the importance on ecology. Because there is no systematic data statistics of related data in these regions, the index weights are mainly according to large amount of literature review and field research. Basic data are mainly received from local governments and villagers during the field research. According to the importance of factors on people's production and living, these factors are estimated and classified.

3.1 Evaluation on the suitability of ecological construction of gully villages

The suitability evaluation refers to qualitative and quantitative evaluation of ecological conditions and developing situation of villages according their present ecological conditions and social developing conditions, thus summarizes the suitability and limitations of each factor. These factors are further classified and used to establish optimum servicing system for villages' construction (Qingmei-Meng, 1999).

Evaluation on the suitability of ecological construction is based on weighted grading method (Yansong & Xiaohang, 2011). Firstly, identifying the evaluation factors that have influence on the villages' ecological suitability, and then investigating the distribution and characteristics of each factor and classifying them. Secondly, according to the effects on the villages' ecological construction, factors' importance should be identified. More weights should be put to those factors that own more effects on ecological construction. Finally, on the basis of classification, all factors should be weighted sum, thus get the comprehensive evaluation value for suitability. The main ideas are as following:

(1) The selection and classification of suitability evaluation factors. The factors' suitability can] classify into 5, 3, 1, which can also be used to show the suitability levels of ecological construction of gully villages (Hanxue, 2007).
(2) Assessment and evaluation of the weight value of each factor, and drawing a hierarchical graph for each factor.
(3) Single factor is stacked and classified according to the stacked results.
(4) According to the result of suitability evaluation, factors are divided into three different ranges: suitable, more suitable, not suitable, and the suitability of ecological construction are divided into good, general and poor.

3.1.1 Selection and explanation of evaluation factors

According to different influence factors on production, living and adapting methods, and documents utility, author selected the following ten evaluation factors: ①slope gradient of both slopes in gullies, ②gully width, ③surface water, ④per capita cultivated land, ⑤population size, ⑥transportation, ⑦village land using degrees, ⑧soil productivity, ⑨plants diversity, and ⑩public infrastructure.

(1) Slope gradient of both slopes in gullies

The influence caused by slope gradient is one of the most important factors for land suitability. According to the research of runoff plots of soil and water conservation, if the slope gradient is within 30°and under the same utilization conditions, the bigger the slope gradient, the soil and water erosion will be worse, thus slope gradient and soil and water erosion is positive correlated (Mao-sheng, Qian-long, Yu-hua & Wei, 2011).. The bigger the slope gradient is, geological will be more instability, ecological environment will be vulnerability, and soil productivity will be lower. The weight is 0.100.

- Slope gradient <5°:basically is flat land, soil erosion which is suitable land for village development. The evaluation value is 5.
- Slope gradient 5°~25°:have a certain slope gradient, which can be use for terrace field. There are limitations for villages' development. The evaluation value is 3.
- Slope gradient >25° : slope gradient is large, the farmland there should be returned into forest or grass land. The limitation for villages' development is large. The evaluation value is 1.

(2) Gully width

Gully width directly limits the scale of village land use, land area, thus affecting the development of the whole village. The weight is 0.125.

- Gully width>300m: land can satisfy the land demand for village development, and there are enough developing space. The evaluation value is 5.
- Gully width 100m~300m: land scale is general and there is not too much space for further development. The evaluation value is 3.

- Gully width <100m: land scale is too small and not suitable for villages' development. The evaluation value is 1.

(3) Surface water

- Surface water is one of the most important elements for wild animals, and also very important for natural ecological system. Thus water area is a judge standard. The weight is 0.075.
- Gully villages are located in the area of reservoir and the coverage area. The evaluation value is 5.
- Gully villages are located in the coverage area of rivers or springs. The evaluation value is 3.
- Gully villages are located in the no water area. The evaluation value is 1.

(4) Per capita cultivated land

Per capita cultivated land is the most important production condition and essential guarantee for certain productivity. The weight is 0.100.

- >3.0 mu/per: villagers have large area of production land and in good condition, thus good living conditions can be guaranteed. The evaluation value is 5.
- 1.5:3.0 mu/per: Production land is enough and villagers' living conditions can be guaranteed. The evaluation value is 3.
- <1.5 mu/per: Production land is not enough and in bad conditions, villagers' life is very hard. The evaluation value is 1.

(5) Population size

Population size is the basic element to ensure the villager development. The weight is 0.100.

- >300: population is large and developing conditions are related mature, which is suitable for further development. The evaluation value is 5.
- 100~300: Population is moderate and developing conditions are relatively common, which can be reserved and developed. The evaluation value is 3.
- <100: Population is relatively small and developing conditions are relatively poor, which is better to move to other places. The evaluation value is 1.

(6) Transportation

Transportation is the main index to measure the accessibility and convenience among cities and towns, which own the positive relation with villagers' development degree (Zhi-ming, Dong & Yan-zhao, 2009). Numerous gullies, fragment landform and lower accessibility are the main characteristics of gully villagers' transportation, thus transportation is one of the most important index that influence the ecological construction and planning of gully villagers. The weight is 0.100.

- Transportation joint: the joint of logistics, energy flow, information flow and species flow. The evaluation value is 5.
- Beside transportation thoroughfares: the place that logistics, energy flow, information flow and species flow pass. The evaluation value is 3.
- Faraway from transportation thoroughfares: the place that far away from logistics, energy flow, information flow and species flow. The evaluation value is 1.

(7) Village land using degrees

Village land using degree is an important influence factor for developing invest and construction, which is also one of the basis for deciding villagers developing directions during the process of planning. The higher degree of land using means the larger population and the bigger developing potential. It is how that the proportion of existing residential area. The weight is 0.100.

- Village land using degree>30%:the proportion of residential land using is high. The evaluation value is 5.
- Village land using degree 5%~30%:the proportion of residential land using is relatively high. The evaluation value is 3.
- Village land using degree <5%:the proportion of residential land using is low. The evaluation value is 1.

(8) Soil productivity

Soil productivity refers to the food production capacity and quantity in farmland per unit, and also the comprehensive reflection of effective thickness of soil layer, soil organic elements, and water condition and soil texture. The weight is 0.125.

- High productivity: effective thickness of soil layer >200cm, soil organic elements >1.2%, soil texture is medium loam, no soil erosion. The evaluation value is 5.
- Medium productivity: effective thickness of soil layer 100~200cm, soil organic elements 1~1.2%, soil texture is light loam, soil erosion is middle degree. The evaluation value is 3.
- Low productivity: effective thickness of soil layer <100cm, soil organic elements <1%, soil texture is sandy loam, soil erosion is high degree. The evaluation value is 1.

(9) Plants diversity

Plants play very important ecological functions in protecting natural sources, and stabilizing gully and slope, soil and water conservation, improvement of fragile ecological environment and anti-interference ability, reduction of ecological sensitivity variation. Plants can be classified in the following three kinds according to their species, areas and values. The weight is 0.075.

- Dense forest zone: mainly with natural vegetation and rich in wild animals. The evaluation value is 5.
- Half forest and half tillage zone: mainly with artificial vegetation and farmland plants. The evaluation value is 3.
- No vegetation zone: mainly with farmland plants and without natural vegetation and wild animals. The evaluation value is 1.

(10) Public infrastructure degrees

Public infrastructure is the important guarantee for life, the developing level of which is one of the important elements to measure the degree of life convenience. The weight is 0.100.

According to the conditions and distribution, and take the reference of the public infrastructure standards, public infrastructure can be divided into good, general and poor.

3.1.2 Standards for the suitability of ecological construction

According to the grading standards of single factors, hierarchical graph can be made and the evaluation results of single factors should also be stacked. Using weighting factor method to evaluate, the following is computational formula:

$$S_i = \sum_{k=1}^{n} B_{ki} W_k \qquad \text{(Equation 1)}$$

In the equation:

i ——refers to the name of gully village, whose ecological construction conditions will be evaluated.

k ——refers to the serial number of evaluation factors for ecological suitability evaluation.

n ——refers to the total number of factors for ecological suitability evaluation.

W_k ——weight value of factor k for ecological suitability evaluation, $W_1 + W_2 + \ldots + W_k = 1$.

B_{ki} ——suitability evaluation value of factor k in gully village i.

S_i ——comprehensive evaluation value of ecological suitability in gully village i.

3.2 Ecological sensitivity evaluation of gully villagers' ecological construction

Ecological sensitivity refers to the ecological factors' adaptability under the outside pressure or interference without damage or lower environmental quality (Jun, Ming-ming, Hai-Jun, Sheng, Jun-qing & Wen, 2014). Different ecological system responses differently for human activities, some of them own strong resistance, while some systems are fragile. The aim of ecological sensitivity is to analyze the responses of village natural ecological system to human activities.

Factors' weighted grading method is adopted for evaluating the ecological sensitivity of gully villages. Firstly, identifying the evaluation factors that have influence on the villages' ecological sensitivity, and then investigating the distribution and characteristics of each factor and classifying them. Secondly, according to their effects on the villages' ecological construction, factors' importance should be identified. More weights should be put to those factors that own more effects on ecological construction. Finally, on the basis of classification, all factors should be weighted sum, thus get the comprehensive evaluation value for sensitivity.

The basic method is as following:

(1) The selection and classification of ecological sensitivity factors. The factors' sensitivity can classify into 5, 3, 1, which can also be used to show the sensitivity levels of ecological construction of gully villages (Hanxue, 2007).

(2) Deciding the weights of each factor and evaluating one by one, and making the hierarchical graph for each factor.

(3) Single factor is stacked and classified according to the stacked results.

Ecological factors	Evaluation standards	Classification	Evaluation value	Weights
Slope gradient of both slopes in gullies	The smaller the Slope gradient is, the higher suitability of ecological construction	<5° 5°~25° >25°	5 3 1	0.100
Gully width	The wider the gully is , the higher suitability of ecological construction	>300m 100m~300m <100m	5 3 1	0.125
Surface water	The better the surface water is, the higher suitability of ecological construction	reservoir and the coverage area rivers and springs No water areas	5 3 1	0.075
Per capita cultivated land	The larger the per capita cultivated land is, the higher suitability of ecological construction	>3.0 mu/per 1.5~3.0 mu/per <1.5 mu/per	5 3 1	0.100
Population size	The larger the population size is, the higher suitability of ecological construction	>300 people 100~300 people <100 people	5 3 1	0.100
Transportation	The better the transportation is , the higher suitability of ecological construction	Transportation joint transportation thoroughfares Faraway from transportation thoroughfares	5 3 1	0.100
Village land using degrees	The higher the village land using degrees are, the higher suitability of ecological construction	>30% 5%~30% <5%	5 3 1	0.100
Soil productivity	The better the soil productivity is, the higher suitability of ecological construction	High productivity Medium productivity Low productivity	5 3 1	0.125
Plants diversity	The more diversity the plants are, the higher suitability of ecological construction	Dense forest zone Half forest and half tillage zone No vegetation zone	5 3 1	0.075
Public infrastructure degrees	The higher lever the public infrastructure degrees are, the higher suitability of ecological construction	Good General Poor	5 3 1	0.100

Table 1. Standards and weights of suitability evaluation factors in gully villages' ecological construction.

In Table 1, the comprehensive value of all stacked factors is changing within 1.00~5.00, in order to combine the future developing strategy with suitability evaluation, this paper divides the suitability evaluation into three levels: ①3.70<S≤5.00, villages with good suitability of ecological construction ②2.40<S≤3.70 villages with general suitability of ecological construction ③1.00<S≤2.40 villages with poor suitability of ecological construction

(4) According to the result of sensitivity evaluation, ecological sensitivity values can be divided into three degrees: high, general, and low ecological sensitivity, villages can be divided accordingly into high, general and low ecological sensitivity villages.

3.2.1 Selection and explanation of evaluation factors

Taking the gully nature and social economy into consideration, there are mainly six limitation factors: ①slope gradient of gully slopes, ②soil erodibility, ③surface runoff sediments, ④soil and water loss, ⑤plant coverage, ⑥pollution. Table.2 analyzes the different influence degrees of human activity of these six factors.

(1) Slope gradient and length of both slopes

Slope gradient and length is an important factor that influences soil erosion sensitivity. Under a certain condition, the same slope gradient but longer slope, the kinetic energy of water flow is larger, soil erosion intensity is higher, geological conditions is less stable, thus it is very sensitive for human activity. The weight is 0.250.

- Slope gradient <5°, slope length <12m: basically is flat land and the ideal land for village development. The evaluation value is 5.
- Slopes gradient 5°~25°, slope length 12m~60m: have a certain slope gradient, which can be used for terrace field. There are a certain limitations for villages' development. The evaluation value is 3.
- Slope gradient >25°slope length >60m: the slope is large, slope gradient is large, the farmland there should be returned into forest or grass land. The limitation for villages' development is large. The evaluation value is 1.

(2) Soil erodibility

The higher the soil erodibility is, the erosion sensitivity will be higher. The weight is 0.250.

- Sandy soil, clay. The evaluation value is 5.
- Light loam. The evaluation value is 3.
- Medium loam. The evaluation value is 1.

(3) Surface runoff sediments

Surface runoff sediments is the most direct motivation for soil and water loss, thus kinetic energy of surface water and sediment movement is the most important factor to evaluate the soil erosion sensitivity. The weight is 0.100.

- Runoff and sediments collecting area. The evaluation value is 5.
- Runoff and sediments source area. The evaluation value is 3.
- Runoff and sediments formative area. The evaluation value is 1.

(4) Soil and water loss

The more serious the soil erosion means that ecology is more sensitive to human activity, which can be divided into serious, the evaluation value is 5; general, the evaluation value is 3; and slight, the evaluation value is 1. The weight is 0.150.

(5) Plants coverage

The rain erosion and kinetic energy of water flow can be reduced greatly if the soil is covered by plants. At the same time, rainfall infiltration and surface runoff can be increased, thus reduces the soil erosion. Therefore, plants coverage is an important factor that influences soil erosion sensitivity. The weight is 0.150.

- Plants coverage >90% : means that plant coverage area accounts for more than 90% of unit area. The evaluation value is 5.
- Plants coverage 50%~90% : plant coverage area accounts for 50%- 90% of unit area. The evaluation value is 3.
- Plants coverage <50% : plant coverage area accounts for less than 50% of unit area. The evaluation value is 1.

(6) Pollution

- Pollution caused by industry, agriculture, domestic pollution, can be divided into high, the evaluation value is 1; medium, the evaluation value is 3; and low, the evaluation value is 1. The weight is 0.100.

3.2.2 Standards for the sensitivity levels of ecological construction

According to the hierarchical graph of single factors, factors should be stacked. Then using weighting factor method to evaluate, the following is mputational formula:

$$S_i^{'} = \sum_{k=1}^{n} B_{ki}^{'} W_k^{'}$$ (Equation 2)

In the equation:

i ——refers to the name of gully village, whose suitability of ecological construction will be evaluated.

k ——refers to the serial number of evaluation factors for ecological suitability evaluation.

n ——refers to the total number of factors for ecological suitability evaluation.

$W_k^{'}$ ——the weight value of evaluation factor for i type ecological construction, $W_1 + W_2 + \ldots + W_k = 1$.

$B_{ki}^{'}$ ——suitability evaluation value of factor k in gully village i.

$S_i^{'}$ ——comprehensive evaluation value of ecological construction method is gully village i.

In table 2, the comprehensive value of all stacked factors is changing within 1.00~5.00, in order to combine the future developing strategy with sensitivity evaluation, this paper divides The suitability evaluation into three levels:
①3.70<S≤5.00 villages with high ecological sensitivity
②2.40<S≤3.70 villages with general ecological sensitivity
③1.00<S≤2.40 villages with poor ecological sensitivity.

3.2.3 Comprehensive evaluation of gully villages' ecological construction

According to the ecological suitability and sensitivity evaluation of gully villages, the developing conditions can be divided into good, general and poor:

- Good means that the comprehensive evaluation for ecological suitability >3.70, and ecological sensitivity ≤2.40.
- General means that the comprehensive evaluation for ecological suitability >2.40, and ecological sensitivity≤3.70.
- Poor means that the comprehensive evaluation for ecological suitability <2.40, and ecological sensitivity >3.70.

Table 2. Standards and weights of sensitivity evaluation factors in gully villages' ecological construction.

Ecological factors	Evaluation standards	Classification	Evaluation value	Weights
Slope gradient and length	The bigger the slope gradient and length is, the higher s ensitivity of ecological construction	>25°, <12m 5°~25°, 12m~60m <5°, >60m	5 3 1	0.250
Soil erodibility	The higher the soil erodibility is , the higher sensitivity of ecological construction	Sandy soil, clay Light loam Medium loam	5 3 1	0.250
Surface runoff sediments	The more surface runoff sediment is, the higher sensitivity of ecological construction	Runoff and sediments collecting area Runoff and sediments source area Runoff and sediments formative area	5 3 1	0.100
Soil and water loss	The more serious the soil and water loss is, the higher sensitivity of ecological construction	serious general slight	5 3 1	0.150
Plants coverage	The more the plants coverage is , the higher sensitivity of ecological construction	<50% 50%~90% >90%	5 3 1	0.150
Pollution	The more serious pollution is , the higher sensitivity of ecological construction	high medium low	5 3 1	0.100

3.3 Developing strategy of gully villages

If the self-conditions is the basic requirement for the ecological construction and social development of gully villages, then the ecological developing conditions of surrounding villages also play an important role in it. On the basis of quantitative and qualitative analyses of self-conditions of gully villages, this paper also analyze the relationship between gully villages and the surrounding villages. The surrounding villages' developing level can influence the developing directions of gully villages directly and indirectly.

Combine with the surrounding villages' developing situation, Table 3 analyzes the future developing directions for gully villages with different ecological construction conditions.

4. Typical case analyses and research: the strategically ecological construction of Liu Zhu He village and Chen Jia He village in Chang Wu County

In order to show the detailed method and procedures of ecological construction of gully villages in Loess Plateau, the papertakes two typical third level tributary villages, Liu Zhu He village and Chen Jia He village in Chang Wu County, Xian Yang city, Shaanxi Province as examples. There are three reasons why choose these two villages as study objects:

(1) Typicality

Located in the sub-region of Northern Wei River area in Loess Plateau, Chang Wu County is a typical gully region in Loess Plateau, where more than 35% villages are typical gully villages. What is more, located in the third level tributary of Hei River, gullies are relative integrity and own many different types and well protected gully villages.

Table 3. Standards and weights of sensitivity evaluation factors in gully villages' ecological construction

Distribution of surrounding villages	Ecological self-conditions of gully villages	Future developing directions
Large villages with good developing conditions	Good	Villages can develop by themselves, and also can be merged into the surrounding villages with better developing conditions.
	General	It is better to be merged into the surrounding villages with better developing conditions, and also they can develop by themselves.
	Poor	These villages should be merged into the surrounding village with better developing conditions.
General size villages with general developing conditions	Good	It is better to develop independently, and also they can merge into the surrounding villages.
	General	Villages can develop by themselves, and also can be merged into the surrounding villages with better developing conditions.
	Poor	These villages should be merged into the surrounding villages with better developing conditions.
Small size villages with poor developing conditions	Good	These villages should merge with the small size villages with poor developing conditions.
	General	These villages can develop by themselves, and also can be merged into the surrounding villages with better developing conditions.
	Poor	These villages can merge with the surrounding villages, and also can be moved to other areas.
No villages distribution	Good	These villages should develop independently.
	General	These villages should develop independently, and also can be move to other areas.
	Poor	These villages should be move to other areas.

(2) Randomness

Liu Zhu He village and Chen Jia He village owns the characteristics of randomness. Both of these two villages located in the third level tributary and close neighbors, their developing conditions and village scales are similar. Considering from their developing conditions, locations and inter-relationships, such kind of objects' selection is random.

(3) Villages' developing relationship

This paper not only studies about the ecological construction conditions of one village, but also studies on its neighbor villages. Though studies on all of these neighbor villages together, it is more scientific to know the factors that influence ecological development.

4.1 Overview of Liu Zhu He village and Chen Jia He village in Chang

4.1.1 Overview of Ding Jia town

Ding Jia town is located in 2.5km, the southwest of Chang Wu county in Shaanxi province, the north of it is flat tableland, the south is gully, the total area is about 32.9 square kilometers (Figure 16). Chang Ling road and 312 National Road are through there, thus it has convenient transportation system and advanced economy (Figure 17, Figure 18). There are 11 villages in Ding Jia town, including 6 administrative villages and 5 gully villages (Local chronicles Compilation Committee of Shaanxi Province, 2000).

4.1.2 The present situation of Liu Zhu He village and Chen Jia He village

Liu Zhu He village and Chen Jia He village are close neighbors, 15 km faraway from town and boarding on Gao Ping county, Jing Chuan town, Gan Su province to the west (Figure 19, Figure 20, Figure 21).

(1) The present situation of Liu Zhu He village

Liu Zhu He village is located in the west of Chen Jia He village, and divided into two production groups by a third level tributary

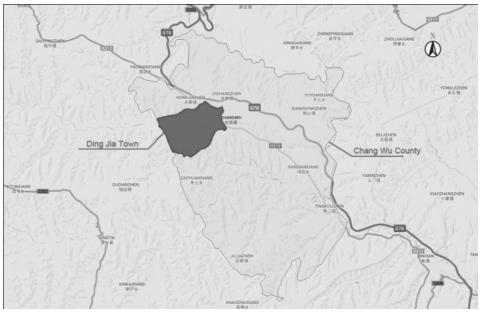


Figure 16. The location of Chang Wu County in Shaanxi province.

Figure 17. The distribution of villages and roads in Ding Jia town.

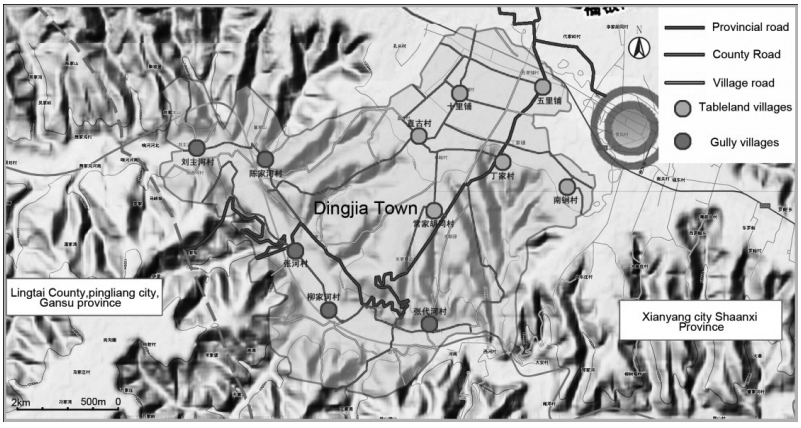


Figure 18. The present situation of Ding Jia town of Chang Wu couty.

(a) Main road in Ding Jia town (b)Landform of gully regions in Ding Jia town

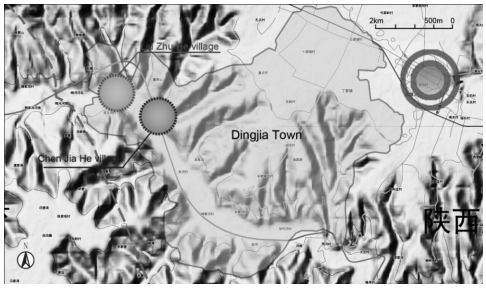


Figure 19. The location of Liu Zhu He village and Chen Jia He village in Ding Jia town.

Figure 20. Land and road distribution in Liu Zhu He village and Chen Jia He village.

Figure 21. Land distribution in Liu Zhu He village and Chen Jia He village.

of Hei River. There are about 66 families with total population of 280, the water source there is sufficient, soil is fertile, and sunshine is adequate. There are about 42.53 hectares cultivated lands, while the net income per person is 2100RMB (343USD) annually, which actually is one of the poorest villages in this area (Local chronicles Compilation Committee of Shaanxi Province, 2000). Planting, aquaculture and labor service export are the main industries, in which wheat and corn are the main plants; fruits and vegetation are also planted; cattle is the main livestock. The public infrastructure is not well established, and there is only one clinic (Figure 22).

Figure 22. Present situation of Liu Zhu He village.

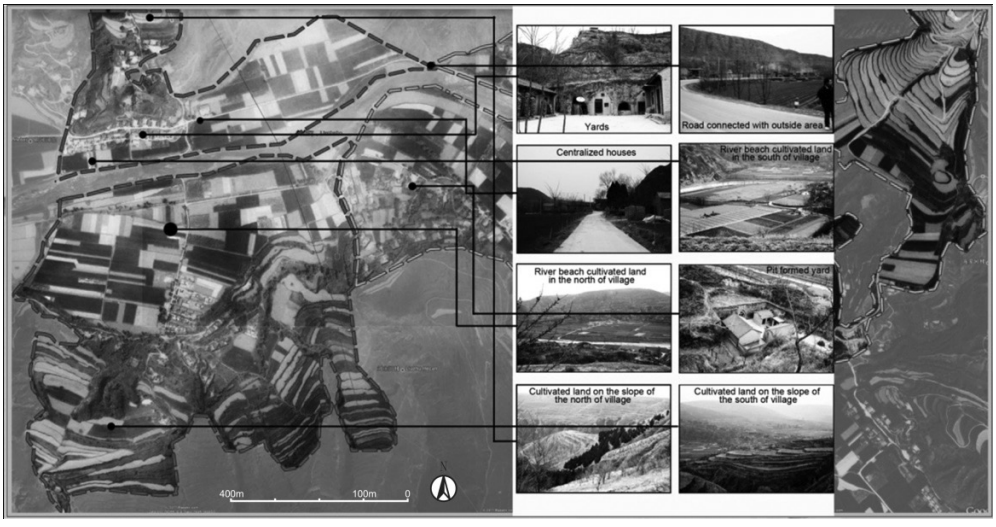
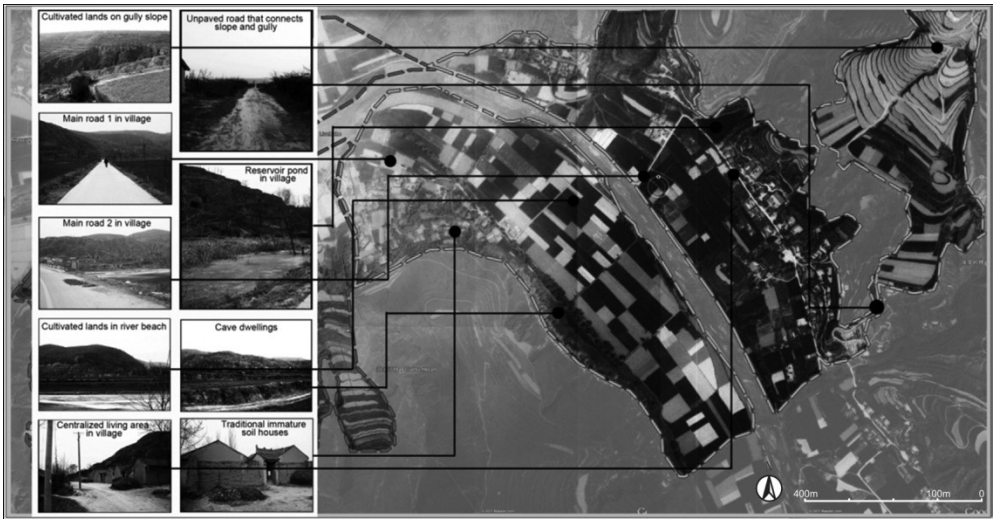


Figure 23. Present situation of Chen Jia He village.



(2) Present situation of Chen Jia He village
In Chen Jia He village, there are about 1386 families with total population of 410, the water source there is sufficient, soil is fertile, and sunshine is adequate. There are about 61.3 hectares cultivated lands, while the net income per person is 2250RMB (367 USD) annually, which actually is one of the poorest village in this area (Local chronicles Compilation Committee of Shaanxi Province, 2000). Planting, aquaculture and labor service export are the main industries, in which wheat and corn are the main plants, fruits and vegetation are also planted, cattle is the main livestock. The public infrastructure is not well established, and there is only one clinic (Figure 23).

4.2 Quantitative analysis of ecological developing conditions in Liu Zhu He village and Chen Jia He village

4.2.1 Quantitative analysis of ecological developing conditions in Liu Zhu He village

(1) Quantitative analysis about the suitability of ecological construction through data collection and practical investigation in Liu Zhu He village (Table 4).

Factors in Table 4 are weighted and stacked to get the comprehensive value that is 3.45. According to the classification of ecological suitability, Liu Zhu He village owns the general suitability for ecological construction.

(2) Quantitative analysis about the sensitivity of ecological construction through data collection and practical investigation (Table 5).

In Table 5, after stacking, clustering of single factors and maximum value of comprehensive value is 2.5. According to classification of ecological sensitivity, Liu Zhu He village is the generally ecological sensitivity village.

4.2.2 Quantitative analysis of ecological developing conditions in Chen Jia He village

(1) Quantitative analysis about the suitability of ecological construction through data collection and practical investigation in Chen Jia He village (Table 6).

In Table 5, after stacking, clustering of single factors, the maximum value of comprehensive value is 3.8. According to classification of ecological suitability, Chen Jia He village is the good ecological suitability village.

Ecological factors	Present situation	Evaluation value	Weights
Slope gradient of both slopes in gullies	5° ~ 25°	3	0.100
Gully width	>300m	5	0.125
Surface water	rivers and springs	3	0.075
Per capita cultivated land	1.5 ~ 3.0 mu/per	3	0.100
Population size	100 ~ 300 people	3	0.100
Transportation	transportation thoroughfares	3	0.100
Village land using degrees	>30%	5	0.100
Soil productivity	Medium productivity	3	0.125
Plants diversity	Half forest and half tillage zone	3	0.075
Public infrastructure degrees	General	3	0.100

Table 4. Evaluation of the ecological suitability in Liu Zhu He village.

Ecological factors	Present situation	Evaluation value	Weights
Slope gradient and length	Gradient 5° ~ 25°, Length 12m~60m	3	0.250
Soil erodibility	Light loam	3	0.250
Surface runoff sediments	Runoff and sediments source area	3	0.100
Soil and water loss	slight	1	0.150
Plants coverage	50%~90%	3	0.150
Pollution	low	1	0.100

Table 5. Evaluation of the ecological sensitivity in Liu Zhu He village.

Table 6. Evaluation of ecological suitability in Chen Jia He village.

Ecological factors	Present situation	Evaluation value	Weights
Slope gradient of both slopes in gullies	5° ~ 25°	3	0.100
Gully width	>300m	5	0.125
Surface water	Reservoir and the coverage area	5	0.075
Per capita cultivated land	1.5 ~ 3.0 mu/per	3	0.100
Population size	>300 people	5	0.100
Transportation	Transportation thoroughfares	3	0.100
Village land using degrees	>30%	5	0.100
Soil productivity	Medium productivity	3	0.125
Plants diversity	Half forest and half tillage zone	3	0.075
Public infrastructure degrees	General	3	0.100

Table 7. Evaluation of the ecological sensitivity in Chen Jia He village.

Ecological factors	Present situation	Evaluation value	Weights
Slope gradient and length	Slope gradient 5° ~ 25°, length 12m ~ 60m	3	0.250
Soil erodibility	Light loam	3	0.250
Surface runoff sediments	Runoff and sediments source area	3	0.100
Soil and water loss	Slight	1	0.150
Plants coverage	50%~90%	3	0.150
Pollution	Low	1	0.100

(2) Quantitative analysis about the sensitivity of ecological construction through data collection and practical investigation (Table 7).

In Table 6, after stacking, clustering of single factors, the maximum value of comprehensive value is 2.5. According to classification of ecological sensitivity, Chen Jia He village is the generally ecological sensitivity village.

4.3 Suggestions on the village development of Liu Jia he village and Chen Jia He village

Through the analyses and evaluation, maximum value of comprehensive value in Liu Zhu He village is 3.45 for ecological sensitivity, and 2.5 for ecological suitability, thus Liu Jia He village own general ecological suitability and sensitivity; while in Cheng Jia He village, 3.8 for ecological suitability and 2.5 for ecological sensitivity, and it owns good suitability and general sensitivity.

Nowadays Liu Zhu He village and Chen Jia He village are close neighbors, 15 km faraway from town and boarding on Gao Ping county, Jing Chuan town, Gan Su province to the west (Figure 12, Figure 13). Both of these two villages are located in the main gully of third brand gully and close with each other, while far away from other cities and villages, and also independent village from each other, which actually is not good for their ecological construction and further development. Therefore, if Liu Zhu He village can be integrated into Cheng Jia He village in the future development, the village scale will be larger, and there will be more resources. Actually, such integration is good for the ecological construction, and guarantees enough cultivated lands, thus comes to be a basic human settlement point with a certain population and public infrastructure during the process of ecological construction.

5. Conclusions

China, as the largest developing country in the world, is experiencing rapid development now. Along this rapid development and recent socialist new rural construction, gully villages of Loess Plateau are also experiencing great change. How to make them achieve a better development in the future comes to be a big challenge for this region. At the same time, as one of the most fragile ecological area in China, how to improve their soil and water protection, ecological system, also is very significant during the whole developing process.

This paper studies on the gully villages of Loess Plateau in detailed, which are very typical while toward "death" in recent years, and find out factors that influence ecological construction and development. The classification of suitability and sensitivity factors of ecological construction makes that possible to evaluate the efficiency of ecological construction by qualitative and quantitative evaluation, at the same time provides the basis for ecological management.

However, human living ecological environment of gully village is continuous developing, these independent and limited index factors are impossible to reflect the overall functions, structure relationships, developing levels and tendency. The comprehensive index system is not the necessary and sufficient conditions and these standards are not absolute suitable for ecological construction;
they must combine with specific time, space and social conditions. Therefore, what provide
here are only relative reference, which are imprecise and periodically. This paper hopes
to explore a new way for the future development of gully villages, and gives the reference and guidance for the better and scientific development in the future.

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